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SECTION 5.1

FOOD & AGRICULTURE
WINE FERMENTATION

(Updated May 2004)

EMISSION INVENTORY SOURCE CATEGORY
Industrial and Other Processes

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION
420-408-6090-0000 (47068) Wine Fermentation

METHODS AND SOURCES

This category is an inventory of the ethanol emissions resulting from the fermentation of grape juice at wineries to produce wine.

During the fermentation process, sugar in the grape juice reacts with yeast to form alcohol (ethanol) and carbon dioxide (CO_2) gas. Ethanol is emitted into the atmosphere through evaporation. According to Williams and Boulton[1], the only important mechanism for ethanol loss is equilibrium evaporation into the escaping CO_2 stream. The physical entrainment of ethanol droplets in the CO_2 gas is insignificant in modern enclosed fermentation vessels.

Wine production in California was reported by the U.S. Alcohol and Tobacco Tax and Trade Bureau (TTB)[2] to be 919,020,025 gallons in 2001. This statewide production of wine is also reported by month by the TTB[2]. The annual production data was reported on a county basis by year upon request from ARB staff, however the monthly production by county was not provided. The amount of wine produced in each county, airbasin, and district (COABDIS) region was then disaggregated by apportioning the 2001 county total according to the permitted maximum amount of wine each COABDIS region can produce.

The Department of Alcoholic Beverage Control[3] (DABC) permits the wine production activities at each winery in the state, limiting them to a maximum amount of wine production each year. This data is aggregated and reported at the airbasin and county level (Table I).

The emission factors used in estimating ethanol emissions during wine fermentation are as follows: white wine - 2.5 lbs. ethanol/1000 gallons wine and red wine - 6.2 lbs.

ethanol/1000 gallons wine produced. These emission factors were derived by the ARB Stationary Source Division (SSD) staff[4] from a computer model developed by Williams and Boulton.[1] The model simulates the effects of fermentation temperature and the sugar concentration in the fermenting juice on the amount of evaporative ethanol loss during isothermal batch fermentation. Results show that the ethanol loss is proportional to the square of the sugar concentration in the juice and that as fermentation temperature increases, ethanol loss increases exponentially.[1] These researchers reported a good agreement between the estimates of ethanol loss using the model with available experimental measurements.

Using these emission factors and the activity data expressed as gallons of wine produced, ethanol emissions were estimated for the two different types of wine: white and red. The relative proportion of the two types of wine produced in California were based on California Agricultural Statistics Services GRAPE CRUSH FINAL REPORT, 2001-2002 CROP[5]. The amount of wine grapes crushed for red wine and white wine was used to estimate the ratio of these wines produced in the state. A composite emission factor of 4.6 lb/1000 gal of wine produced was derived by using this ratio of wine types produced (see sample calculations).

The statewide ethanol emissions for 2001 from wine production are presented by airbasin and county in Table II.

ASSUMPTIONS

1. Wine production is proportional to the permitted wine production limit, which can be used to apportion the county wine production totals to the COABDIS regions.

2. The amount of grapes crushed for each type of wine is proportional to the amount of that type of wine produced, which can be used to apportion the amount of wine produced into the amounts of red and white wine produced.

3. The relative ratios of red and white wines produced in California are the same for all regions in the state.

4. The monthly activity profile of wine fermentation does not significantly differ by COABDIS region, and therefore a single statewide monthly profile can be used.

5. The emission factors taken from the Williams and Boulton model run generated by the ARB Stationary Source Division (SSD) are the best available to represent the amount of evaporative ethanol loss from the fermentation of wine.

COMMENTS AND RECOMMENDATIONS

The current procedure for estimating ethanol emissions from wine fermentation has the following limitations:

1. The estimated wine production in each COABDIS region calculated by disaggregating the county level wine production data based on the permit limits for wine production may not accurately reflect the actual wine production in each COABDIS region. This is because the permit limit is not a measure of actual production but of maximum allowable production. Each winery will set this level based on business considerations. However, this is a reasonable surrogate and should not skew the breakout of wine production by COABDIS region to any great degree.

2. The monthly activity of wine production in each COABDIS region will vary from region to region. The assumption that all regions have the same monthly activity is in error, but given that the only monthly data currently available is at the statewide level, this error is still better than the even worse assumption of uniform activity throughout the year, which is the only alternative.

3. The ratios of white to red wine are based on crushed grape ratios and that for the state. This leads to two possible errors. The first being the amount of wine produced by crushing a given mass of white wine grapes may not be equal to the wine produced by crushing the same mass of red wine grapes. The second is the assumption that all counties have the same ratio of production of red to white wine.

A survey of the wine producing districts could be conducted to obtain COABDIS region specific data on a) actual wine production by month, and b) relative ratios of the different types (red and white) of wine produced.

CHANGES IN METHODOLOGY

The current methodology has changed the method and surrogate used to determine wine production by COABDIS region from those used in the previous 1992 update. The method for determining the temporal distribution of wine fermentation emissions has also changed, but the emission factors have remained the same, with the only difference being that all wines are now grouped into only two categories, red or white, whereas the previous methodology included a third category: rose wines.

Previously, amounts of grapes crushed by wine district and amount of grapes produced by county were used to disaggregate the statewide wine production to the counties, but this has a greater potential for error than the current method. Grapes crushed are only recorded at the wine district level, and had to be further disaggregated itself to the county level using the amount of grapes produced by county. Unfortunately, grapes produced in a county may not be used by that county,

being shipped to another place for production of wine for example. Nor will all the grapes produced even be used for wine. Some are used for table grapes, making raisins and making grape juice. This introduced error in dividing up the wine to the counties. Furthermore, grapes crushed in a district may not be used in that district, being shipped to another place for the actual production process. The new method has a more solid surrogate to distribute wine production not just to the county level, but to the COABDIS region level as the permit limit used is a production limit (not a limit on grapes grown or crushed) and directly related to each winery's ability to produce wine.

The temporal factor changes reflect the discovery of a new data source from the TTB, which breaks out wine production by month on a statewide basis. Although not broken out on a more detailed level, this statewide breakout is still much better than the old estimate that used the best estimate and judgement of ARB staff.

TEMPORAL ACTIVITY

Ethanol emissions are distributed monthly based on the 2001 reported wine production at the statewide level for that month. During each month, it is assumed that emissions occur 24 hours per day and seven days a week.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.9	3.6	1.2	0.7	0.9	1.1	0.8	9.7	28.0	26.1	11.5	10.6

SAMPLE CALCULATIONS

A. Calculate statewide ratios of white and red wine production.

Determine the process rate (tons of grapes crushed) for each type of wine compared to the total tons of grapes crushed for wine production in 2001.

CA red wine production ratio = 1,706,036.9 tons red wine grapes crushed/ 3,005,957.7 tons of all wine grapes crushed
= 0.568 (56.8%)

CA white wine production ratio = 1,299,920.8 tons white wine grapes crushed/ 3,005,957.7 tons of all wine grapes crushed
= 0.432 (43.2%)

B. Calculate composite emission factor.

Red wine TOG emission factor (6.2 lb/1000 gallons) x 0.568 +
White wine TOG emission factor (2.5 lb/1000 gallons) x 0.432 = 4.6 lb/1000 gallons

REFERENCES

1. L.A. Williams & R. Boulton. Modeling and Prediction of Evaporative Ethanol Loss During Wine Fermentation, American Journal of Enology and Viticulture, 32:234-242, (1983).

2. http://www.ttb.gov/alcohol/stats/index.htm

3. California Department of Alcoholic Beverage Control, David Kurano (916) 263-6872.

4. Air Resources Board, A Suggested Control Measure for Control of Ethanol Emissions from Winery Fermentation Tanks, a Technical Support Document Prepared by the Energy Section, Stationary Source Division, ARB, California, (October 1991).

5. http://www.nass.usda.gov/ca/bul/crush/Final/2002/200203gcbtb01.htm

UPDATED BY

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Table I

Wine Production Permit Limits in California by Airbasin and County (1000 Gallons)

County Name	Airbasin	Maximum Allowed Wine Production
ALAMEDA	SF	7,560
AMADOR	MC	2,905
BUTTE	SV	65
CALAVERAS	MC	1,315
CONTRA COSTA	SF	105
EL DORADO	MC	1,275
FRESNO	SJV	113,190
HUMBOLDT	NC	70
KERN	SJV	21,205
LAKE	LC	4,375
LASSEN	NEP	5
LOS ANGELES	SC	1,175
LOS ANGELES	MD	10
MADERA	SJV	19,370
MARIN	SF	95
MARIPOSA	MC	45
MENDOCINO	NC	15,285
MERCED	SJV	59,005
MODOC	NEP	5
MONTEREY	NCC	23,430
NAPA	SF	84,415
NEVADA	MC	150
ORANGE	SC	20
PLACER	SV	45
PLACER	MC	5
RIVERSIDE	SC	2,085
RIVERSIDE	SS	20
SACRAMENTO	SV	1,055
SAN BENITO	NCC	13,465
SAN BERNARDINO	SC	30
SAN DIEGO	SD	330
SAN FRANCISCO	SF	25
SAN JOAQUIN	SJV	120,500
SAN LUIS OBISPO	SCC	30,865
SAN MATEO	SF	160
SANTA BARBARA	SCC	10,145
SANTA CLARA	SF	5,700
SANTA CRUZ	NCC	2,955
SHASTA	SV	10
SISKIYOU	NEP	15
SOLANO	SV	15
SOLANO	SF	225
SONOMA	NC	47,660
SONOMA	SF	26,985
STANISLAUS	SJV	63,055
TEHAMA	SV	5
TRINITY	NC	40
TULARE	SJV	16,020
TUOLUMNE	MC	30
VENTURA	SCC	145
YOLO	SV	5,240
YUBA	SV	105
TOTAL		**702,010**

Table II

2001 Area Source Emissions
Activity: Wines & Brandy
Process: Food & Agricultual
Entrainment: Process Loss
Dimn: Fermentation (Wine) Wine
CES: 47068
Process Rate Unit: 1000 Gallons Produced

AB	County	Process Rate (1000 Gallons)	TOG Emissions (Tons/Year)
LC	LAKE	1,587	3.65
MC	AMADOR	1,382	3.18
	CALAVERAS	1,056	2.43
	EL DORADO	517	1.19
	MARIPOSA	15	0.03
	NEVADA	8	0.02
	PLACER	0.2	0.0004
	TUOLUMNE	25	0.06
MD	LOS ANGELES	9	0.02
NC	HUMBOLDT	57	0.13
	MENDOCINO	13,928	32.03
	SONOMA	80,580	185.33
	TRINITY	6	0.01
NCC	MONTEREY	25,774	59.28
	SAN BENITO	263	0.61
	SANTA CRUZ	1,332	3.06
NEP	LASSEN	1	0.003
	MODOC	1	0.003
	SISKIYOU	4	0.01
SC	LOS ANGELES	1,038	2.39
	ORANGE	0.04	0.0001
	RIVERSIDE	1,412	3.25
	SAN BERNARDINO	81	0.19
SCC	SAN LUIS OBISPO	17,718	40.75
	SANTA BARBARA	6,264	14.41
	VENTURA	47	0.11
SD	SAN DIEGO	118	0.27
SF	ALAMEDA	1,790	4.12
	CONTRA COSTA	709	1.63
	MARIN	89	0.21
	NAPA	93,017	213.94
	SAN FRANCISCO	48	0.11
	SAN MATEO	810	1.86
	SANTA CLARA	7,666	17.63
	SOLANO	636	1.46
	SONOMA	45,624	104.93
SJV	FRESNO	1,658	3.81
	KERN	2,348	5.40
	MADERA	205,588	472.85
	MERCED	111	0.26
	SAN JOAQUIN	259,385	596.58
	STANISLAUS	139,995	321.99
	TULARE	741	1.70
SS	RIVERSIDE	14	0.03
SV	BUTTE	22	0.05
	PLACER	2	0.004
	SACRAMENTO	7	0.02
	SHASTA	3	0.01
	SOLANO	42	0.10
	TEHAMA	0	0
	YOLO	5,437	12.50
	YUBA	54	0.12
TOTAL		**919,020**	**2,113.72**

Fraction of Reactive Organic Gases (FROG): 1.0000
(Reactive Organic Gases (ROG) Emissions = TOG X FROG)